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ENGINES FOR USSR TIMBER-HAULING TRUCKS

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[Tables referred to are appended.]

Articles on machines for hauling timber have appeared in previous issues of Lesnaya Promyshlennost' (No 11, 1949; No 7 and 12, 1950); the present article is a discussion of engines for railless timber hauling.

The KT-12 skidding tractor was the first specialized machine for hauling timber. ZIS-5, ZIS-21, and ZIS-150 trucks and S-65, SG-65, and S-80 crawler tractors are widely used for hauling, but they are not specifically designed for the timber industry.

Wide experience with ZIS-21 and ZIS-5 trucks shows that for timber hauling the power of these trucks must be increased, the power transmission and the undercarriage strengthened, the trucks' roadability improved, and special mechanisms added. However, such changes would amount to building new, special timber-hauling trucks.

The basic requirements of an engine for a special timber-hauling truck are as follows:

1. The engine should operate on generator gas from green wood and scraps from felled wood.

2. The engine should be adapted to the variable loads encountered in hauling timber, that is, it should have ample torque at low and medium rotation speeds, and it should be flexible.

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3. The engine should have sufficient power for truck trains hauling timber over uneven roads where there is comparatively high resistance to motion.

4. The engine should have a device to facilitate cold-weather starting.

5. Units and parts of the engine should have high wear resistance.

6. The engine should be simple and accessible for servicing and repair.

Experience shows that the ZIS-21 engine does not have sufficient power for truck-train hauling of timber under difficult road conditions. Moreover, the ZIS-21 engine does not have ample hauling power for the KT-12 tractor, which is equipped with this engine.

In calculating the maximum horsepower of an engine for timber-hauling trucks, it must be kept in mind that the timber is hauled on dirt roads or snow-covered roads, as stated in "Specifications for Planning and Building Logging Enterprises," 1949. The coefficient of [road] resistance was chosen on the basis of the above-mentioned specifications. ZIS-21, ZIS-150, and ZIS-151 trucks with 1-AP5 semitrailers, 2-PR10 trailers for dirt roads, and the AOS-6 trailer for snow-covered roads were selected for the calculations.

It was further assumed that loads would be hauled by truck trains on normal level roads or roads with small grades, and that loads would be hauled by trucks and semitrailers on roads with sharp grades or with minimum preparation of the surface.

The working load for the calculations was set at the rated load of the trucks and trailers for hauling timber on good roads, and the maximum speed was set at 25 kilometers per hour. Results of the calculations are given in Table 1.

The table shows that engines with a maximum horsepower of 60-70 and 100-110 are required for hauling timber.

The compression ratio of gas-generator engines varies from 6.0 to 8.5 in engines with 5.55 liters' displacement (ZIS-21, ZIS-120, ZIS-21VK, ZIS-21M) and directly affects the mean effective pressure.

Increasing the compression ratio beyond 8.0 does not produce any appreciable increase in the mean effective pressure. In the ZIS-21VK engine, the maximum increment in pressure is attained not only by considerably increasing the compression ratio, but also by using overhead intake valves and increasing the timing phase.

The efficacy of supercharging depends on the compression ratio and decreases as the compression ratio increases.

Moreover, it becomes increasingly difficult to start the engine as the compression ratio increases. Therefore, the compression ratio should be set between 7.5 and 8.5.

The coefficient of flexibility of automobile and tractor engines is equal to 1.1-1.4, the higher figure corresponding to the low-speed engine. Flexibility is especially important in timber-hauling trucks, since it makes driving easier, decreases the amount of gear shifting on roads where the grade changes frequently, reduces wear of the transmission, and assures good hauling characteristics.

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For these reasons, we conclude that a low-speed engine is best for a timber-hauling tractor truck, although it entails increasing the engine's displacement.

For modern special tractor trucks, the coefficient of rotation-speed variation is as high as 80, and the transmission ratio of the main transmission is as high as 12.

Normal values of the coefficient of rotation-speed variation and the transmission ratio of the main transmission at the maximum speed of 20-25 kilometers per hour are possible only when the rotation speed of the engine does not exceed 2,000 revolutions per minute. At 2,000 revolutions per minute and 20 kilometers per hour, these values will still be somewhat higher than on engines of modern design.

The rotation speed of the engine at the given maximum horsepower defines the displacement of the engine. For the given maximum horsepower, the rotation speed must be between 1,800 and 2,000 revolutions per minute. A further increase in the rotation speed will not reduce the displacement markedly and will only bring the external characteristics of the low-speed engine close to those of high-speed engines.

Moreover, experience shows that the highest mean effective pressure is obtained at comparatively low rotation speeds. If we compare two engines with the same rotation speed, the mean effective pressure will be greater for the engine with the greater displacement.

The mean effective pressures (according to experimental data) of engines with a working volume of 5.5 liters, a rotation speed of 2,000 revolutions per minute, and operating on generator gas are shown in Table 2.

Taking the indexes of the ZIS-21 engine without supercharging for comparative calculations, we find that at 1,800 revolutions per minute and a mean effective pressure of 3.6 kilograms per square centimeter, the displacement of the engine must be 8.35 liters and its approximate weight 620 kilograms to obtain a maximum of 60 horsepower; to increase the maximum horsepower to 70 and 110, the displacement must be enlarged to 9.75 and 15.3 liters, respectively, and the approximate weight raised to 720 and 1,130 kilograms, respectively.

These excessive weights, two or three times as great as those of modern engines of equal power, are caused by large displacement and low mean effective pressure.

Let us consider three methods of increasing the mean effective pressure.

The first method consists of increasing the cross section of intake valves and passages, increasing the timing phase, eliminating preheating of the working mixture, increasing the compression ratio, and improving the combution chamber. These methods of supercharging were used on standard ZIS-21VK and ZIS-21M engines and should be kept in mind when new engines are built.

The second method, called partial supercharging, consists of forcing the working mixture in at a pressure of a 40-50 millimeter mercury column. The kindling fan of the KT-12 tractor can be used for this purpose with only minor changes. Partial supercharging is most effective at high rotation speeds and is best used when slight increases in horsepower are desired without complex changes in design. For series produced ZIS-21 engines, partial supercharging raises the mean effective pressure (at high rotation speeds) 10-15 percent.

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The third method is full supercharging, using a pump of the volumetric type. The Scientific Research Automobile and Tractor Institute carried out research on a ZIS-120 engine operating on generator gas and using a volumetric supercharger. The tests showed that the mean effective pressure increased 30 percent at low speeds, 50 percent at medium speeds, and 70 percent at high speeds, as compared to operation without the supercharger. An even greater increase in the mean effective pressure was achieved by changing the gear ratio of the pump to increase its speed and by using a corrective device to control the degree of supercharging.

Raising the mean effective pressure is best done by full supercharging, and the use of superchargers does not entail any special difficulties, since they are series-produced and are used on a number of engines (the YaAZ-204 and the YaAZ-210). However, further laboratory and field tests of supercharged gas-generator engines are necessary.

Given a compression ratio of 7.5-8.5 and a rotation speed of 1,800-2,000 revolutions per minute, the only way to obtain comparatively small displacement is to use a volumetric supercharger.

The most acceptable parameters of engines using a volumetric supercharger and developing 60 and 70 horsepower are given in Table 3.

To obtain 110 horsepower, using a volumetric force pump, it would be necessary to increase the working volume of the engine beyond 10 liters and thus raise its weight above 750 kilograms. The construction of large-displacement engines operating on generator gas would necessitate larger gas generators, for while a 60-70 horsepower engine requires 140-160 kilograms of gas per hour, a 110-horsepower engine requires 250 kilograms of gas per hour.

The productivity of series-produced transport gas generators (e.g., the SG-65) is as much as 145 kilograms of gas per hour, and it would be easy to increase it to 160 kilograms per hour. But a transport gas generator capable of producing 250 kilograms of gas per hour would be cumbersome, heavy, and inconvenient to use. Thus, the construction of gas-generator engines of more than 70-80 horsepower is impractical.

For heavy timber-hauling tractor trucks requiring more than 100 horsepower, series-produced diesel engines (the YaAZ-204, the YaAZ-210, and the D-6) should be used.

Conclusions based on the preceding data are as follows:

Engines developing a maximum horsepower of 60-70 and 100-110 are most suitable for hauling timber by truck.

Forced ZIS-21VK and ZIS-21M engines may be adapted for use as 60-70 horsepower engines by using supercharging. The productivity of the series-produced gas generator should be correspondingly increased.

However, the use of forced ZIS-21VK and ZIS-21M engines for timber-hauling trucks is only a temporary measure, since the comparatively high rotation speed at maximum power and the marked forcing of the working process reduce the life of these engines.

An engine with a working volume of 6.7 liters, a compression ratio of 8.0, and a rotation speed of 1,800 revolutions per minute would meet the requirements for timber hauling. Such an engine could develop 50-55 horsepower on generator gas. Partial supercharging would raise this figure to 60 horsepower, and a volumetric force pump would raise it to 70 horsepower.

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Such an engine could be designed for future conversion to diesel fuel. Using diesel fuel, it could develop 80 horsepower; with partial supercharging, 90 horsepower; and with a volumetric force pump, 100-110 horsepower. Thus, by consecutive improvements, such an engine could serve as a prototype for a group of transport engines for the timber industry developing 50-55, 60, and 70 horsepower (generator gas); and 80, 90, and 100-110 horsepower (diesel fuel).

/Appended tables follow./

Table 1. Required Maximum Horsepower of Engines for Timber-Hauling Trucks Under Various Hauling Conditions

Type Road	Rolling Stock	Dead Wt (tons)	Pay Load (tons)	Gross Vehicle Wt (tons)	Max Hp
	ZIS-21				
Dirt	Semitrailer 1-AP5	4.57	6.0	10.57	48.0
Dirt	Trailer 2-PR10	6.17	14.0	20.17	97.4
Snow covered	Semitrailer AOS-6	4.36	9.0	13.36	38.2
Snow covered	Trailer AOS-6	5.53	21.0	26.53	67.5
	ZIS-150				
Dirt	Semitrailer 1-AP5	5.37	8.0	13.37	61.4
Dirt	Trailer 2-PR10	6.97	16.0	22.97	105.0
Snow covered	Semitrailer AOS-6	5.16	10.0	15.16	41.0
Snow covered	Trailer AOS-6	6.33	22.0	28.33	73.3
	ZIS-151				
Dirt	Semitrailer 1-AP5	6.87	9.0	15.87	73.5
Dirt	Trailer 2-PR10	8.47	17.0	25.47	117.9
Snow covered	Semitrailer AOS-6	6.66	10.5	17.16	52.1
Snow covered	Trailer AOS-6	7.83	22.5	30.33	82.2

Table 2. Mean Effective Pressures of Various Engines

Type Engine	Compression Ratio	Mean Effective Pressure (kg/sq cm)
ZIS-21	6.7-7.0	3.4-3.6
ZIS-21VK, forced	8.5	4.4-4.6
ZIS-21M, forced	8.5	4.4-4.6
ZIS-120, supercharged	6.0	4.4-4.9

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Table 3. Calculated Parameters of an Engine
Equipped With a Volumetric Force Pump

Index	Unit of Measure	60-Hp Engine	70-Hp Engine
Rpm at maximum hp	rpm	1,800-2,000	1,800-2,000
Compression ratio	--	7.5-8.5	7.5-8.5
Mean effective pressure	kg/sq cm	5.2-4.9	5.2-4.9
Displacement	liters	5.75-5.50	6.7-6.4
Torque at maximum hp	kg-m	24.0-21.5	27.8-25.0
Transmission ratio of volumetric force pump	--	0.75	0.75
Estimated weight of engine	kg	425-410	495-475

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